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CROWN DECADENCE OF SUGAR PINE IN RELATION TO
ATTACKS BY THE MOUNTAIN PINE BEETLE

PRELIMINARY REPORT

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By
G. R. Struble
Berkeley, California
February 9, 1942

SUBJECT--

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Craighead

Keen

Euenden

Forest Insect Laboratory
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February 9, 1942

CROWN DECADENCE OF SUGAR PINE IN RELATION TO
ATTACKS BY THE MOUNTAIN PINE BEETLE.
PRELIMINARY REPORT

APPROVED BY:

J. M. MILLER
Senior Entomologist, In Charge

SUBMITTED BY:

G. R. STRUBLE
Associate Entomologist

CROWN DECADENCE OF SUGAR PINE IN RELATION TO
ATTACKS BY THE MOUNTAIN PINE BEETLE.
PRELIMINARY REPORT

Crown decadence among sugar pines and its relation to attacks by the mountain pine beetle may have an important bearing on possible changes necessary to adequately control this insect. Until recently, crown decadence as a measure of susceptibility had not been given serious consideration. Control methods now as in the past, are based on the reduction of beetle broods directly and will probably continue along this line unless present studies on susceptibility will allow for the prediction of trees most apt to be attacked. If characteristics of the crowns among certain trees are found to correlate directly with beetle attacks, then the beetles may be controlled indirectly by logging methods to remove the most susceptible trees.

The success with which the western pine beetle in ponderosa pine is being controlled by this method in northeastern California has opened up the question of its possibilities elsewhere. The mountain pine beetle problem among sugar pines in central California is one meriting considerable attention. Although a different insect, particularly with respect to life history and habits of attack, the mountain pine beetle may be found to confine its attacks to trees having certain characteristics. Investigations of this possibility are now under consideration.

The main objective of this study is to determine what factor or combination of factors within a given area of virgin forest will predispose sugar pine trees to attacks by the mountain pine beetle. Preliminary data on several phases of this study were taken during 1941. These phases are: (1) the establishment of crown decadence types which may be easily recognized; (2) to determine whether susceptibility is correlated with decadence as designated by these types; (3) to determine what factors within the crown are responsible for crown decadence.

The methods of approach to this problem were planned as follows: (1) to establish permanent 20-acre plots for continuous annual records of individual trees to note changes in condition and the relation to the mountain pine beetle; (2) to secure a detailed record of recognized predisposing characters from as many currently killed sugar pines as possible; (3) to study the decadence characteristics of living mature sugar pines before felling and the causes of decadence after felling on commercial logging areas.

Only one of the 20-acre plots was established in 1941. Considerable information was obtained on the other two approaches to the problem, although more is needed as a basis for conclusions. The areas of study included both virgin and cut-over lands on the Stanislaus National Forest, Yosemite National Park, and Sierra National Forest. The work was carried on from the Miami Field Base on the Sierra National Forest.

This preliminary report brings up to date all of the information gathered on this problem during the past season, and aims to point out any significant leads thus far as well as possible weaknesses. The investigations have not yet gone far enough to warrant more than tentative conclusions on certain points.

CROWN DECADENCE CLASSES ESTABLISHED FROM PLOT STUDIES

The first study plot was laid out in a virgin forest considered as typical of the optimum conditions for sugar pine. It is located in the Mariposa Grove area of Yosemite National Park approximately half a mile south of Grizzly Giant big tree. It covers an area of 20 acres and is oriented in an east-west direction with dimensions of 10 x 20 chains. It is tied in with a permanent U. S. Geological Survey benchmark (Elevation 5,906 feet) located on the south boundary of Yosemite National Park near the service road to Mt. Raymond. A detailed map of the plot is shown by Figure 1. Permanent stakes are situated every 5 chains along the boundary and through the center, marking the plot off into $2\frac{1}{2}$ -acre units. The exposure of the plot as a whole is north with some of it facing northwest and some northeast. For the most part the slopes are gentle. The growing conditions indicate Site 1 on the east to site 2 on the west. The annual precipitation during 1940-1941 amounted to 60 inches at the same elevation one mile west of the plot.

The timber on this plot is typical of the Sierra sugar pine type. It is predominantly sugar pine in a mixed stand with white fir, ponderosa pine, and incense cedar. The understory species consist mainly of California black oak. The stocking figures for the plot are as follows:

Species	Trees	Volume	Trees per Acre	Volume per Acre
Sugar pine	229	1,041,670	11.40	52,083.5
Ponderosa pine	32	120,020	1.60	6,001.0
White fir	317	377,160	15.85	18,858.0
Incense cedar	108	92,370	5.40	4,618.5
Total	686	1,631,220	34.25	81,561.0

Losses in sugar pine on the plot for the past 20 years due to the mountain pine beetle are estimated at 15,084 board feet per acre. This figure is based on stumps and snags scattered through the area.

In setting up the plot as a crown decadence study every sugar pine tree of merchantable size 12 inches DBH and over was tagged with a numbered metal tag. Individual detailed records, describing characteristics of probable importance were taken on forms provided for similar

studies in ponderosa pine. Each tree was classified according to crown decadence and, in addition, according to Keen's and Dunning's systems as applied to ponderosa pine for comparison. The decadence class of each tree was then scribed on the bark of that tree. Additional merchantable sized sugar pines within an area 5 chains wide surrounding the plot were assigned crown decadence type classifications on the bark.

Description of decadence types.

This preliminary study resulted in the establishment of 8 tentative crown decadence types with designations from A to H. These designations may prove to be too closely integrated to be of practical use in separating trees of a given character. Four groups or even 3 may prove to be more worth while. The present designations, however, typify the variations in crown character among sugar pines which may be found in a virgin stand. Illustrations of each type are shown by Figure 2*.

Type A: Heavy, full, symmetrical crown with blue green to dark green foliage and pointed or rounded top, without any evidence of injury.

Type B: Moderately heavy symmetrical crown with pointed top, having dark to bluish green foliage, without evidence of injury.

Type C: Medium full, symmetrical crown with pointed top, having light green to bluish green foliage, often with light twig flags or light mistletoe infection.

Type D: Medium full, somewhat irregular crown with slightly rounded top, having light to bluish green foliage, often with light twig flags and/or light mistletoe infection.

Type E: Medium to thin irregular or one-sided crown with top flat or somewhat rounded, having light to dark green foliage, with light or heavy twig flags, some branch kill, often with mistletoe.

Type F: Medium to thin, irregular or one-sided crown with flat top, having light green foliage, twig flags and branch kill common, often with mistletoe infection.

Type G: Thin, irregular or one-sided crown with flat top, foliage thin, yellowish in top and light green elsewhere, twig and branch injury variable, but numerous, frequently with mistletoe infection.

Type H: Thin, irregular or one-sided crown with flat top, having yellowish foliage throughout, heavy twig and branch injury, heavy mistletoe infection causing witches brooms from top to bottom

* Drawings by T. Sagimori, forestry graduate, University of California.

Occurrence of decadence types.

Among the 229 trees of merchantable size the number occurring in each type was found to vary considerably as is shown in Table 1. Considering them from the standpoint of health or decadence there were about as many healthy as decadent appearing crowns. For example, there were 113 healthy crowns represented by Types A, B, C, and D and 116 crowns of varying degrees of decadence represented by Types E, F, G, and H. The more decadent groups contained about 73 percent of the volume, among mature or overmature trees of large size.

Table 1. Distribution of Types on Plot SP-1

Type	Trees		Volume	
	Number	% of Total	Board Feet	% of Total
A	11	5.00	49,050	4.70
B	20	8.00	33,900	3.25
C	48	21.00	105,240	10.10
D	34	15.00	88,670	8.51
E	57	24.00	368,390	35.36
F	40	18.00	278,220	26.70
G	16	7.00	103,170	9.90
H	3	1.00	15,030	1.44

Comparison to Keen's and Dunning's classes.

The decadence type classification differs from the other two systems essentially in that it disregards age and dominance. Hence, even though a given tree may be comparatively young, but with a thin, poorly developed crown, it is classed among older trees having similar crown characteristics. On the plot, which may be considered typical, young dominants and nearly all young co-dominants were found to fall in A, B, or C types, while frequently intermediate and suppressed young trees fell in varying decadent types from E to G. In Keen's classification system these same trees would fall in his 1 or 2 age class and his A, B, or C crown classes within certain limits, and Dunning's 2 and 6 classes. Among the mature dominant sugar pines Dunning's class 5 may vary between Type E and H depending on degree of crown decadence.

Relation to growth rate.

Average growth curves covering a period of 20 years for each group of decadence classes show a definite correlation between growth and degree of decadence as shown by Figure 3. These curves are based on measurements of annual rings from cores taken from every tree on the plot. They indicate that the characters used in judging crown decadence are valid.

RELATION OF CROWN DECADENCE TYPES TO SUSCEPTIBILITY

Immediate information on the relation of crown decadence to beetle attacks becomes available as trees are attacked and killed currently. On the plot there were no trees killed during 1941 and information on the types of trees killed here may not be available for a period of 10 years or more. Records from current attacks on trees scattered over a broad expanse of forest are of considerable help, although they may not be accurate in indicating correlations unless the growing conditions in which they are found are proven to be similar. For example, it is not likely that the growing conditions of trees killed on cut-over areas are the same as for trees in a virgin forest. Trees killed on Site 1 growing conditions may not be legitimately compared to those on poorer sites even though they have the same degree of decadence in the crown.

Evidence of a lack in correlation between attacks by the mountain pine beetle and the degree of crown decadence and by Keen's and by Dunning's classes was found among the comparison of 52 currently killed trees during 1941. These trees occurred on several different sites on virgin and on cut-over areas located on the Sierra National Forest, Yosemite National Park, and Stanislaus National Forest. Keen's and Dunning's classes were assigned to all trees studied for purposes of comparison with the crown decadence system. The results are shown graphically by Figure 4. These results show that the losses among Types B, C, and D constituted 52 percent of the total number of trees studied. Fifty-six percent of the trees studied were medium aged in Keen's 3A and 3B classes, while 40 percent were young to medium aged dominants and co-dominants in Dunning's 2 and 3 classes. The number of trees studied, however, may be too few upon which to base conclusions.

It would appear desirable that intensive studies be continued on sites or in stands of a given type until enough data are available for comparison. One such comparison is available in files of losses on regional survey plots in which all sugar pines killed by the mountain pine beetle were classified by Keen's classes during the period from 1931 to 1939. These data (Figure 5) showed that the mountain pine beetle selected the oldest trees in a substantial majority of cases, indicating that selection is more than a matter of chance as indicated by Figure 4.

On the basis of the information obtained thus far it is impossible to predict which trees of a given sugar pine stand are most susceptible to attacks by the mountain pine beetle. Hence, until considerably more information is obtained and correlations are established, a system of control based on logging out susceptible trees is not justifiable. A logging system in sugar pine based on the removal of mature and overmature or decadent trees on the chance that they may be attacked is far more logical at the present time.

FACTORS CONCERNED IN CROWN DECADENCE

Logging activity at Green's Mill on the Sierra National Forest provided a good opportunity to secure information on the causes of weakening among sugar pine crowns in a virgin forest area. Detailed records were taken on 20 trees before and immediately after they were felled by loggers. The data taken on standing trees included DBH, height, degree of dominance, age, crown length, crown width, crown shape, crown density, twig injury, and branch injury. Each tree was classified according to decadence type and according to Dunning's and Keen's classes. After felling the crown of each tree was examined closely for factors of apparent importance to decadence in foliage, twigs, branches, and trunk.

The data secured at Green's Mill are indicative only of the local conditions found there. Growing conditions indicated Site 2. The exposure is northeast and is broken up by a number of steep slopes, draws, and ridges. The sugar pine stand here can not be considered overmature, for the range in ages of trees examined was found to vary from 175 to 410 years. The oldest trees were selected for detailed study. The average age was 262 years. Fifteen of the 20 trees were mature, one was overmature, and 4 trees were immature. Fifteen trees were dominants, 5 were co-dominants, 1 was an intermediate, and 1 was suppressed.

Detailed examinations of these trees revealed only a few examples in which the health of the tree was definitely impaired. Most of them were found to be healthy regardless of age or crown classification. Only one tree examined was affected by bark beetles and also by flathead borers. Several of the trees were weakened by the effects of heavy growths of mistletoe, and a few were affected by fungi and the presence of a "sour sap" condition. In Table 2 which follows, a detailed record of decadence factors is shown by decadence types.

Table 2. Decadence Factors Found among Different Types

Tree Number	Insects	Disease	Remarks
<u>Type C</u>			
I	Chionaspis pinifoliae	None	Occasional scale on foliage.
XXXI	Leafhoppers	None	Many etiolated spots on foliage.
J-1	None	None	Off-color in mid and lower branches only; upper crown healthy.
<u>Type D</u>			
VI	None	None	Excellent health.
IX	None	None	Excellent health.
XVIII	Chionaspis pinifoliae	Fungus	Occasional scale on foliage. Sour sap condition prevalent throughout trunk weakening it.

Table 2 (continued)

Tree Number	Insects	Disease	Remarks
<u>Type D (continued)</u>			
Stump #38	Incipient flatheads, Dendroctonus valens	None	Upper 1/3 heavy pitch and flatheads
XXVII	Chionaspis pinifoliae	None	Scales scattered on occasional needles
XXIX	None	None	Yellowish foliage top and mid-crown, but no insects.
<u>Type E</u>			
II	Chionaspis pinifoliae and Adelges sp.	None	Occasional scale on foliage. Adelges on new growth of one branch.
VII	Chionaspis pinifoliae	None	Very light. No other injury.
VIII	" "	"	" " " " "
X	" "	"	" " " " "
XXV	Chionaspis pinifoliae	Virus or fungi	Sour sap condition at junction of branches with trunk. Small bunchy witches brooms, occasional scales on foliage.
XXIV	None	Virus or fungi	Sour sap condition in top, causing yellowish foliage.
XXVI	None	Fungus	Heart rot penetrating from old lightning scar making shell out of lower 2/3 of bole.
XXVIII	None	None	Small bunch-type brooms prevalent throughout crown. Cause unknown. No insects.
<u>Type F</u>			
III	None	Mistletoe	Heavy infection throughout crown causing witches brooms.
IV	Ips and Dendroctonus monticolae (Topkill)	Mistletoe	No insect injury below mistletoe. Moderate mistletoe infection throughout living crown.
XXX	Chionaspis pinifoliae	None	Few small bunch-type witches brooms, occasional scales. Crown in good shape.
<u>Type G</u>			
J-2	Chionaspis pinifoliae	Mistletoe	Heavy mistletoe infection causing short yellowish bunchy needles and brooms throughout. Scales found only occasionally.

As seen by this table, there is little or no correlation between decadence type and amount of injury by insects or disease. In other words, trees whose crowns are off color or which have a distinctly decadent appearance may be free from insects or disease. From this it may be inferred that crown deterioration results probably from many factors in addition to insects and disease, such as age, soil characteristics and moisture, etc.

The most decadent crowns in this group were affected heavily by mistletoe. There is little doubt but that this parasitic plant is a distinct weakening agency, not only on mature timber, but also among trees of all ages from seedlings to mature trees. The photographs (Figure 6) show how it affects the growth of seedlings.

On the Green's Mill area insects as a cause of crown deterioration were of minor importance or none at all. The pine leaf scale Chionaspis pinifoliae (Fitch) was found to be the most consistently distributed, but its damage to foliage was not detected on any of the trees in which it occurred. The most evident damage to foliage was in the form of yellowish or etiolated spots, the cause of which was suspected to be associated with leaf-hoppers. Although they were never seen actually feeding on the foliage, the presence of numerous leaf-hoppers seemed to indicate that they may in some way be linked with damage. Two species were identified by P. W. Oman as Aceratagallia lyrata (Bak) and A. californica under Hopk. U. S. 32751.

One type of decadence worthy of some attention was noted in the larger branches, particularly at their junction with the main trunk, where a distinct "sour sap" odor was evident. This condition did not seem to tie in with insect injury anywhere, but was thought to be caused either by fungi or virus infection. If a virus it is conceivable that sucking insects, such as the leaf hopper, may play a part.

Small, ball-like bunchy witches brooms (Figure 7) were commonly found, but the cause of them was not determined. No insects were found which might be linked with broom formation. The presence of this type of broom even when occurring in great numbers, did not appear to affect the general health of the crown.

The results of the studies carried on at Green's Mill must for the present be considered preliminary because of the one locality considered. Similar studies should be extended to include other areas varying as to condition of growth and state of maturity and decadence of crowns in other stands being logged.

SUGGESTIONS FOR FURTHER STUDY

These studies indicate that considerably more information is needed before definite conclusions are justified or before changes in investigative plans are made. On the basis of information obtained so far, it is impossible to say with certainty whether there is no correlation between crown decadence and insect attack. Neither can it be stated that highly decadent crowns are necessarily the result of insect attacks. At the present time we have accomplished the beginning of a difficult problem which may take several years to complete.

In the light of preliminary studies there are suggested several lines of approach which can be followed to good advantage. The first of these is to study dying and currently killed sugar pines until it can be shown definitely whether correlations exist between characters that can be seen and the presence of bark beetles. Data from every local area in which detailed observations are made should be studied separately since local conditions (site, soil moisture, associated timber species, or type of stand) may be highly significant in influencing a mountain pine beetle attack. It is highly important that each factor be isolated and its worth determined. Full use of decadence type classifications should be made, but if possible these classifications should be simplified. There are doubtless more types in the present set-up than can be used without confusion, and it may be feasible to combine into single groups those trees having similar characteristics.

Plot studies of crown decadence should be extended to include several different growing sites and conditions, where close observations and records may be kept on individual trees. These plots should be permanently located and the trees should be tagged in a manner similar to the one established in Mariposa Grove. The location of one of these plots has been proposed at Grizzley Meadow on the Sierra National Forest.

Limited studies on the relation of growth rate to attacks by the mountain pine beetle have indicated that there is no relationship. However, there has as yet been no adequate basis for conclusions. Studies on this relationship should be continued with care taken to compare trees growing under similar conditions.

Studies should be continued on the insects and other factors which may enter into the causes of crown decadence. The data taken from trees at Green's Mill represent only one locality; sugar pines in other localities differing as to site quality and age of trees, should be investigated. Logging operations now in progress should yield this needed information.

So far, insects have been found to be of minor importance in causing crown deterioration, except where tops are killed outright by Ips. Other causes of crown decadence may be attributed to mistletoe, to fungi, and to "sour sap". The cause of "sour sap" condition is unknown, but

may be ascribed to a virus transmitted by insects. There is a possibility that leaf hoppers are involved, and it may be worth while to investigate their habits and possibilities as disease vectors.

It may be necessary to carry investigations beyond visible external characteristics to find an adequate basis for diagnosing susceptibility. Phloem moisture differences, chemical changes within the sap, or some other physiological unbalance may condition sugar pine trees to mountain pine beetle attacks. The highly specialized nature of some of these studies is probably beyond the training of an entomologist and would require the services of one trained in chemistry and plant physiology.

SUMMARY

1. Preliminary studies of crown decadence in relation to attacks by the mountain pine beetle in sugar pine stands followed three lines of approach: (1) the establishment of recognizable crown decadence types; (2) the possibility of correlation between attacked trees and decadence type; (3) the factors responsible for crown decadence.

2. Eight different types of crowns based on degree of health or decadence were established tentatively as a result of an intensive plot study. These were designated by letters from A to H; A indicating most healthy and H most decadent.

3. Growth comparisons between the different decadence types showed a direct relation of growth to degree of decadence on the basis of annual ring width.

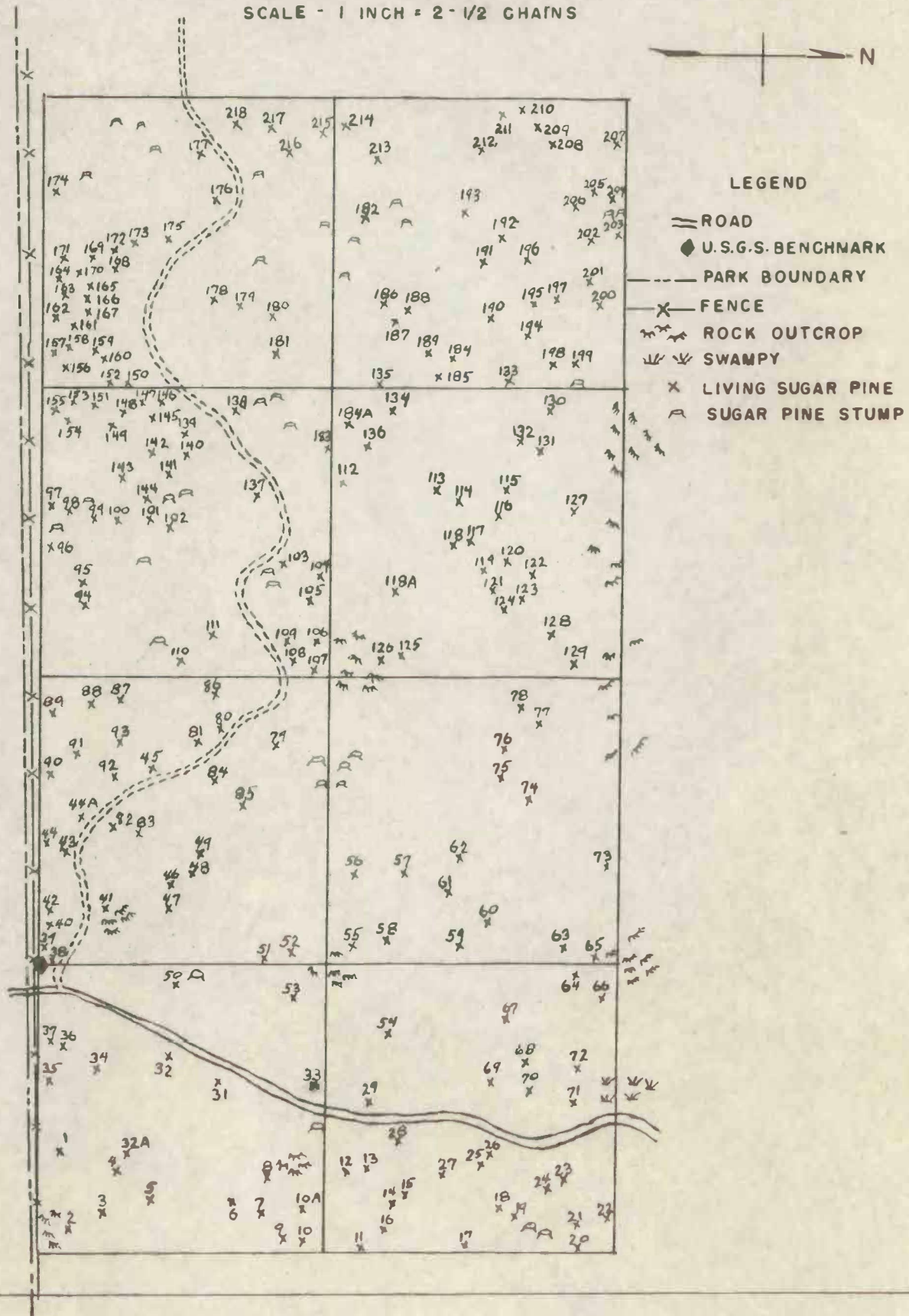
4. Data from 52 currently killed sugar pines from widely scattered areas indicated no direct relationship with the degree of crown decadence as set forth by these decadence types. Conclusions on the basis of this information, however, may not be justified because growing conditions on areas where the dead trees were found were not uniform.

5. Studies of the factors contributing to crown decadence indicated that insects were relatively unimportant among several other factors such as mistletoe, "sour sap" condition, etc. A possible relation between leaf hoppers and virus infection to cause the "sour sap" condition is suggested.

6. Considerably more information is needed on the relation of crown decadence to beetle attacks in sugar pine, before conclusions are justified.

FIGURE 1.
U.S.D.A.
BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE
PLOT SP-1

SUGAR PINE INSECT SUSCEPTIBILITY STUDY
SCALE - 1 INCH = 2 1/2 CHAINS



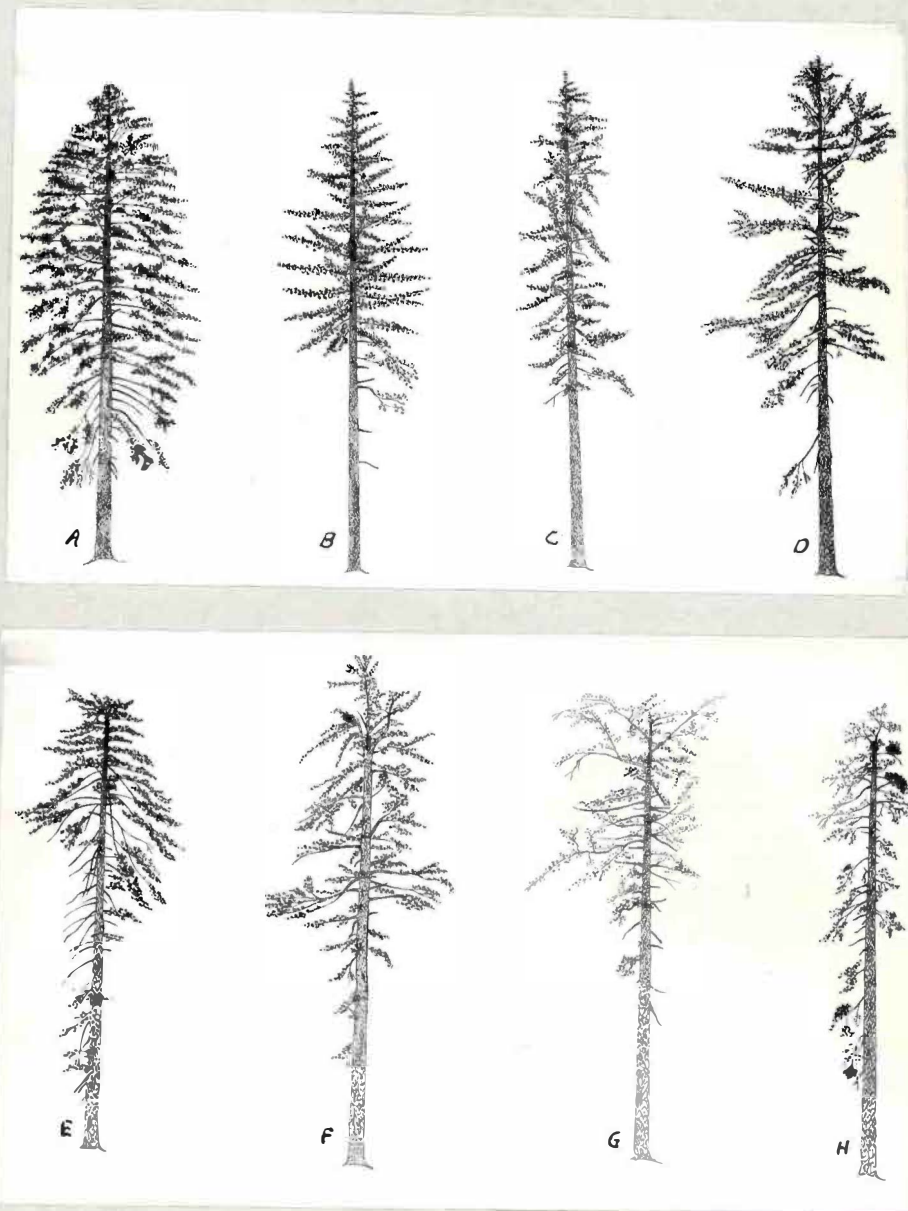


Figure 2.-- Sugar pine crown decadence types.

FIGURE 3
AVERAGE GROWTH RATE OF CROWN DECADENCE
TYPES - PLOT SP-1

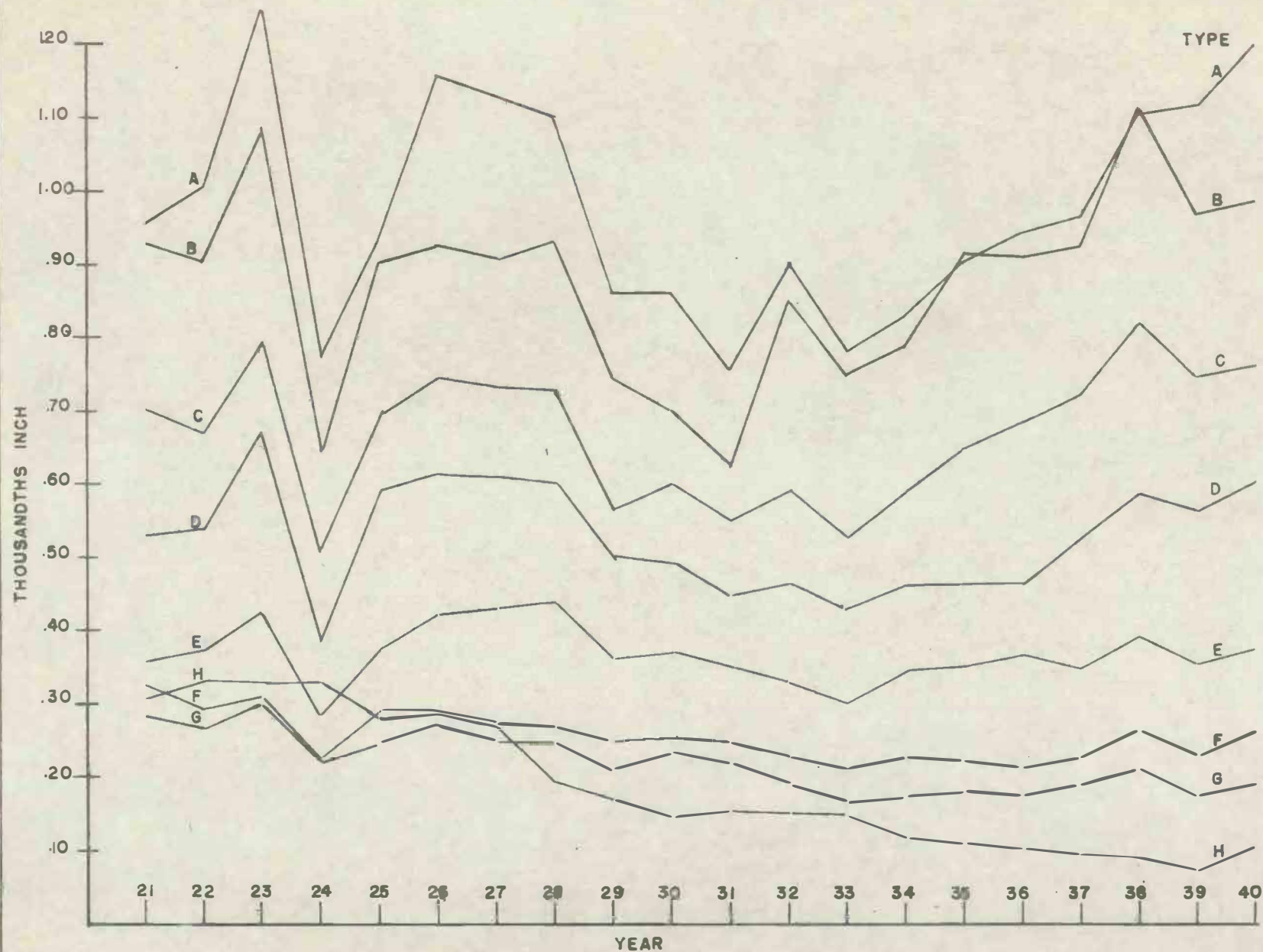


FIGURE 4

DISTRIBUTION OF SUGAR PINES KILLED BY D. MONTICOLAE BY
CROWN DECADENCE AND BY KEEN'S AND DUNNING'S CROWN
CLASSES IN PERCENT OF TOTAL NUMBER RECORDED (52)

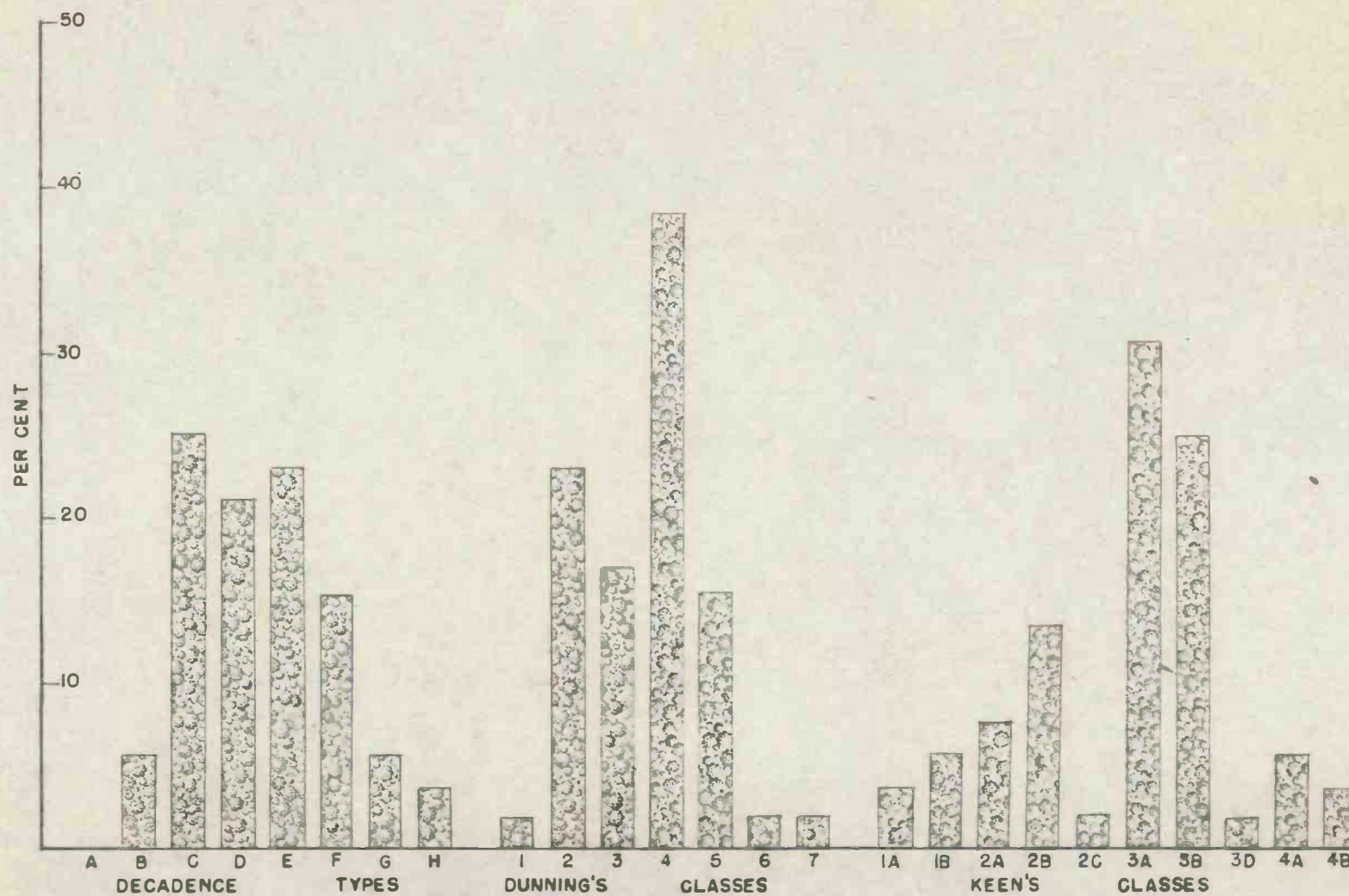


FIGURE 5
DISTRIBUTION OF SUGAR PINES KILLED BY D.
MONTICOLAE ON REGIONAL SURVEY PLOTS 9, 12,
AND 14 FROM 1931 TO 1939 BY KEEN'S TREE
CLASSES IN PER CENT OF TOTAL NUMBER
KILLED (BASIS - 222 TREES)

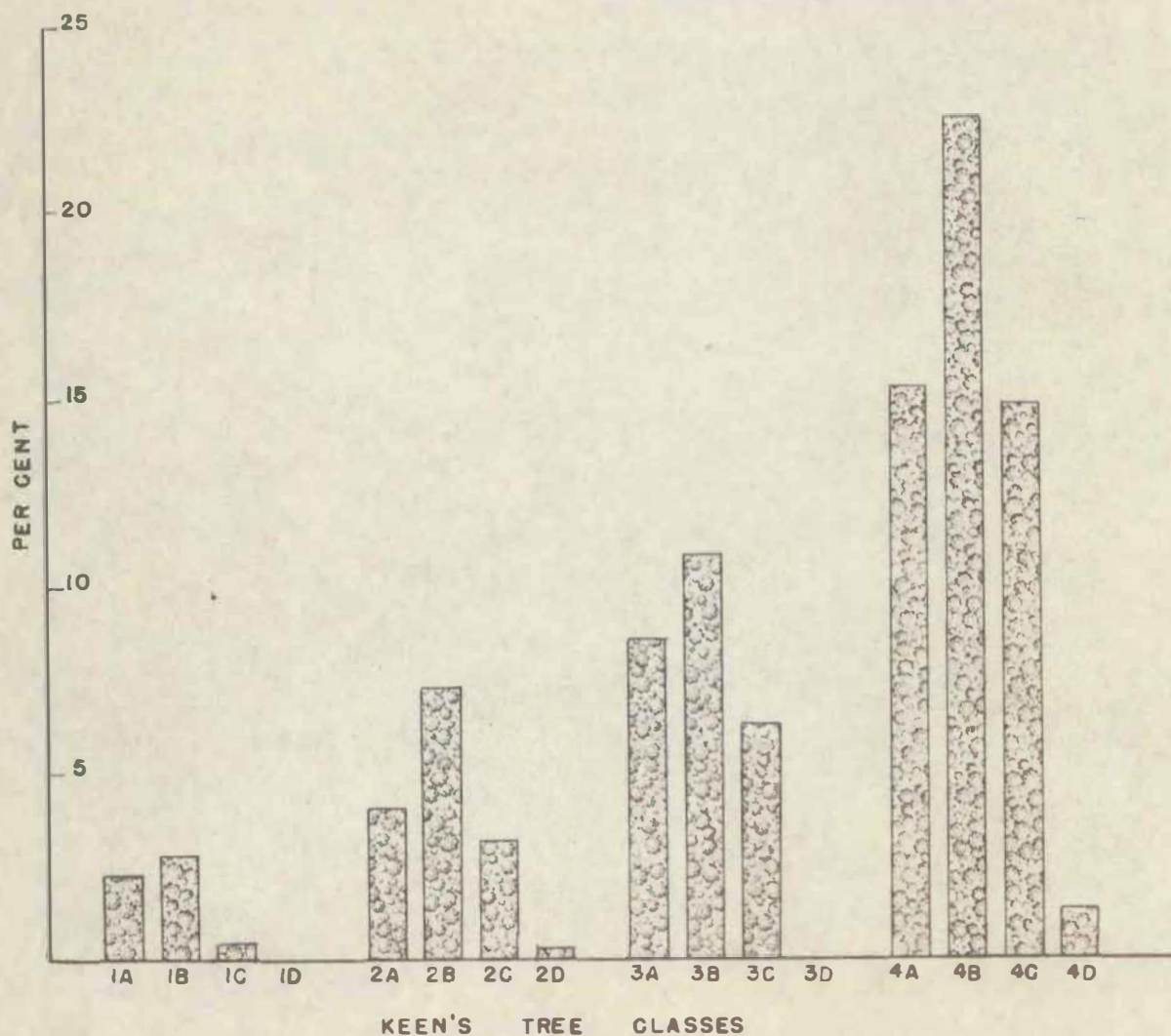


Figure 6. Witches broom formation in sugar pine seedlings stated by W. W. Wagener as probably caused by mistletoe, Arceuthobium campylopodum blumeri, compared with a normal seedling (center). Dwarfed, many branching, swollen stems and short, yellowish foliage are characteristic of this condition.

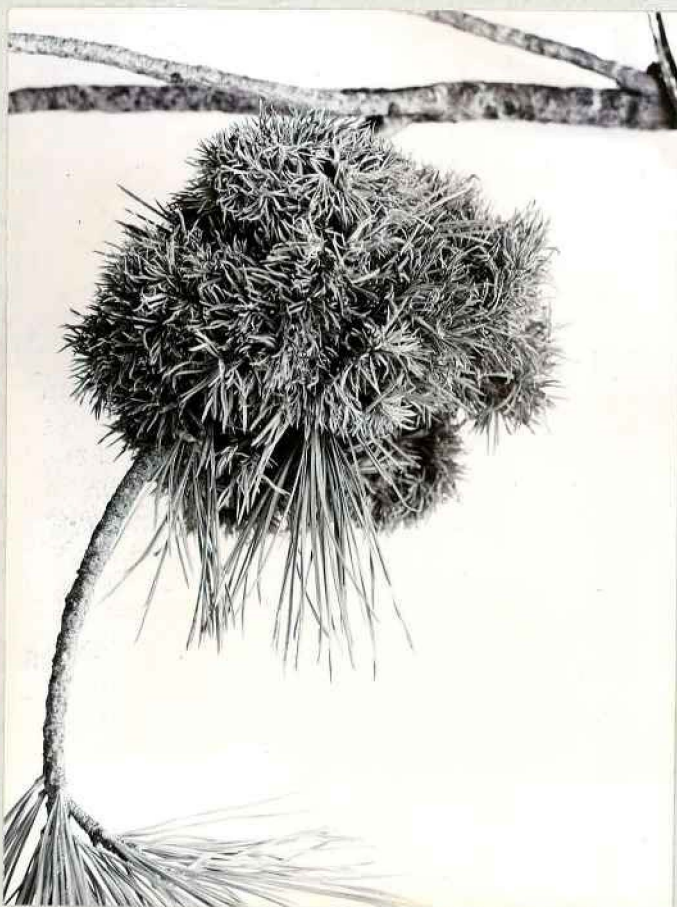
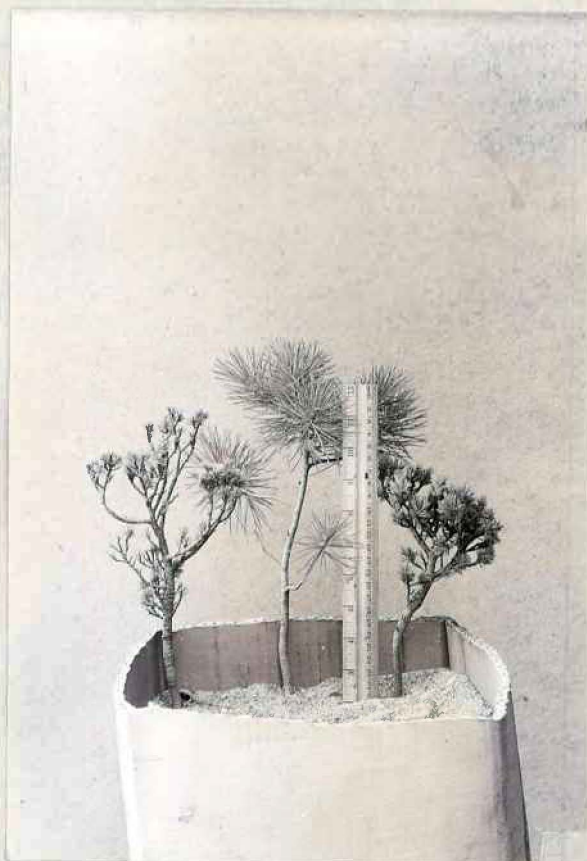


Figure 7. Witches broom formation found frequently in mature sugar pines. No insects or mites were found responsible for this abnormal growth. Note normal foliage projecting below the broom. Individual crowns having numerous brooms of this type were not noticeably weakened.